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A driver assistance system for traffic signs based on machine learning

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Abstract

The aim of this study is to develop a system that recognises traffic signs using artificial neural networks and transfer learning methods, and audibly informs the driver about the recognised sign. In order to realise this idea, a web application has been developed using the machine learning library TensorFlow.Js, which can run in different internet browsers. This web application can run on any desktop or laptop computer with an internet connection and a webcam. Traffic signs are presented to this application by pressing the traffic sign button when the traffic sign enters the camera's field of view. After presenting the traffic sign to the system from different angles and with as many examples as possible, the recognition process is performed automatically.

The traffic sign recognition system has been tested with a web camera mounted on the right rear view mirror of a vehicle, while the vehicle was travelling at a constant speed of 20 km/h in an outdoor environment. An accuracy of 90% was achieved with 20 demonstrations per sign. The success of the system is directly proportional to the samples chosen during training. The system can be generalised by taking samples at different angles, distances and lighting levels. The developed system can be used to teach traffic signs to drivers in driving courses as well as to help drivers to recognise traffic signs accurately and completely. With this system, driver errors due to inattention or ignorance can be minimised, thus making traffic safer and reducing traffic accidents.

Keywords: Traffic signs; Machine learning; Transfer learning; Driver assistance systems

1. Introduction

Traffic accidents cause a high number of loss of life and property every year in the world. The fact that traffic signs and markers are not known correctly and completely by drivers is one of the factors that increase the number of traffic accidents. One of the most important issues in intelligent vehicle design to minimise the number of driver-related accidents is traffic sign recognition systems (Aydın, 2009). For this reason, the correct recognition of traffic signs and markers by drivers is of vital importance in terms of ensuring traffic safety as a whole.

Traffic signs are categorised into five groups: hazard warning signs, traffic regulation signs, information signs, stopping and parking signs, and horizontal signs. Each category is explained briefly below (Anonymous, 1985).

Hazard warning signs are designed to warn drivers of hazards on the road. Traffic regulation signs are used to regulate the flow of traffic, although they usually include special cases. Organisation signs are created for organization. Information signs convey pertinent information to drivers. Signs are installed to provide drivers with important information regarding the road and its surroundings. Stop and parking signs are placed at appropriate locations to indicate where drivers can park their vehicles. There are also signs that are designed to control and organize parking areas. Stop and parking signs are placed at appropriate locations to indicate where drivers can park their vehicles. Additionally, horizontal signs provide directional information indicating the route, destination, or distance to be

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travelled. Road markings are drawn on the surface of roads to control traffic, signal specific prohibitions and restrictions, and provide guidance to road users.

In order to ensure the safe and regular flow of traffic, it is very important that traffic signs are adequate, standard and in the right places, and that their meaning is sufficiently and accurately known by all drivers. For example, if a driver is travelling on a stretch of road where there is a "Narrow Road Sign", and he/she knows the meaning of this sign, he/she can continue to drive safely by taking the necessary precautions such as reducing speed and not overtaking. However, if the driver does not know the meaning of this sign, he/she may face unfavourable situations such as a collision with an oncoming vehicle due to the narrowing of the road, or skidding off the road because he/she does not take precautions.

In a research, it was revealed that drivers do not understand most of the traffic signs they encounter on a daily basis and the number of drivers who know the signs correctly is very low. It was reported that 46% of them were distracted while following traffic signs (Anonymous, 2013).

Today, lots of luxurious and mid-range cars have added features that sound signals to the driver about specific speed limits. These features are designed to identify the numbers found on the speed limit sign. Unfortunately, there isn't a feature that can identify all kinds of traffic signs and alert the driver (Mertoglu, 2017).

In a study conducted in Denizli, one of Turkey's major cities, 27 traffic signs and signs frequently encountered in daily life were selected and a questionnaire consisting of 27 multiple-choice questions was applied (Murat & Cakıcı, 2017). It was determined that approximately 40% of the traffic signs in the questionnaire had medium, low or very low level of awareness and only 25% of these signs had very high level of awareness. In particular, the low level of awareness of traffic signs such as "Uncontrolled intersection" and "Give way" explains the causes of frequent accidents at uncontrolled intersections (Murat & Cakıcı, 2017).

In another study, 190 questionnaires were used to assess the level of understanding of a total of 30 traffic signs (10 warning, 10 traffic control and 10 traffic information signs) by road users and the level of recognition of the signs was found to be 79% (Umar and Bashir, 2019). The least understood sign is "Park and Continue" with a level of awareness of 54.7%. This is followed by "Narrow bridge" (60%), "Merge lane ahead" (62.1%), "Slippery road" (63.2%) and "No vehicle" (70.5%). Signs with a recognition rate of up to 90% are "Petrol station", "Stop sign" and "School crossing". Truck drivers were found to have poorer perception of traffic signs than road users in all other classes (65%) (Umar & Bashir, 2019).

In a survey application, which involved a total of 650 people to measure the level of knowledge and awareness of traffic signs, asked questions about the meaning of 18 traffic signs and found that drivers' and pedestrians' knowledge of traffic signs was inadequate. (Sehribanoglu, 2019).

According to the literature, driver recognition of traffic signs is at a very low level. In this study, we aim to develop a system that recognises traffic signs using artificial neural networks and transfer learning methods, and audibly notifies the driver.

2. Material and Method

2.1. Design of the application developed with different traffic signs

We have developed a system using artificial neural networks and transfer learning to address the problem of inadequate and inaccurate knowledge of traffic signs by drivers.

Sophisticated neural networks typically consist of millions of parameters, and training them from scratch requires both large amounts of data and computational resources. Transfer learning is a method of learning from models that have already been trained many times. With the new model based on this knowledge, machine vision and classification systems can be trained with fewer examples. This ensures continuity of information and allows systems with high classification performance to be developed with less data and lower system requirements.

The web application we developed using the Javascript language and the TensorFlow.js software library detects traffic signs in the image taken by a road camera and speaks the name of the sign for the driver to hear. The developed system is a web application that works in different internet browsers. It can run on any desktop or laptop computer with an internet connection and a webcam. Traffic signs are presented by pressing the sign's button when the sign is in the camera's field of view.

In the design of the application developed for this purpose, a control class was first created with twenty different traffic signs and a camera image representing the absence of traffic signs (Figure 1). For each class, the sign recognition process is performed automatically after demonstration at different angles, at different distances from the camera and with as many samples as possible (Figure 2).

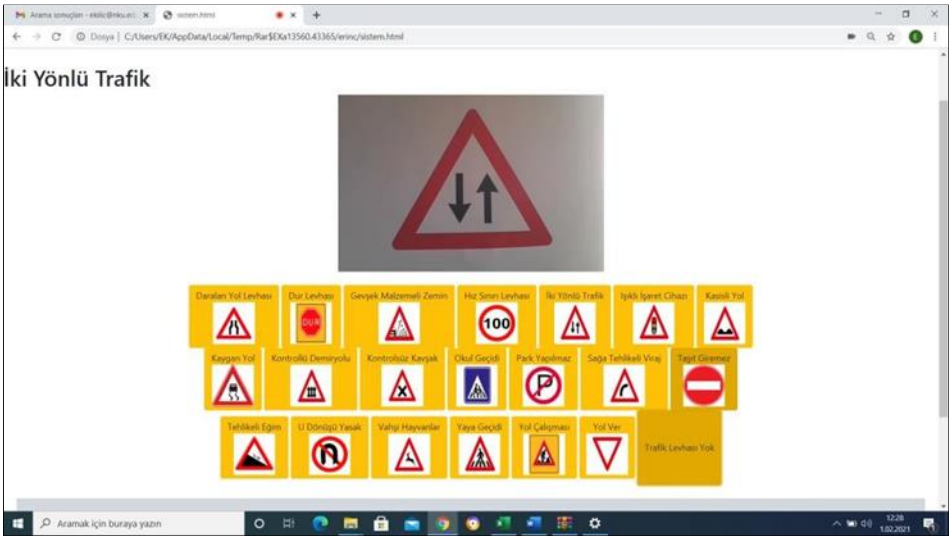

Figure 1 WEB application interface

In order to obtain the experimental measurements, a catalogue of traffic sign models was created by colour printing on A4 sheets. Lenovo Ideapad 510 laptop computer with Intel Core i5 7200U technical specifications was used for this purpose. A4 TECH PK-635G ANTI-GLARE 480P 640x480 WEBCAM was used for image acquisition (Figure 3).

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Figure 2 Training of traffic signs

For the WEB application, each sign was introduced to the system twice, first with 10 photographs and then with 20 photographs at different angles, positions and distances. At the end of each training, the camera was mounted on the right-hand rear-view mirror of a vehicle and tested by detecting 5 different traffic signs and no traffic signs on the road while the vehicle was travelling at a constant speed of 20 km/h (Figure 3). The actual sign and the incorrectly detected signs (or no sign) were recorded and the system's accuracy table was produced.

Due to the scattered structure of traffic signs in the city, the validation tests used the pedestrian crossing, traffic light, speed bump, speed limit and stop signs on the road selected for the experiment and the control group without any signs taken by the camera.

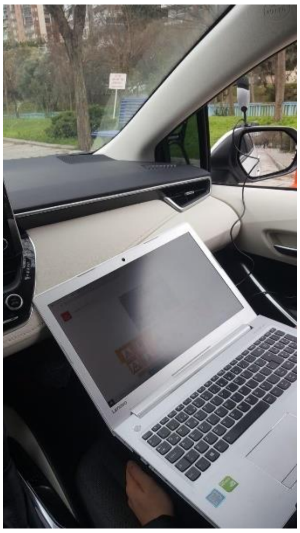

Figure 3 Camera mounted on the vehicle and laptop computer running the system

2.2. The working steps of the software and Javascript codes

In index.html:

<script src="https://unpkg.com/@tensorflow-models/mobilenet"></script> line loads the model used in transfer learning.

The tandem classification algorithm, which we will train with the images we take on the information transferred by transfer learning, is called with the following code.

<script src="https://unpkg.com/@tensorflow-models/knn-classifier"></script>

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<script src="https://unpkg.com/@tensorflow-models/knn-classifier"></script>

The functional properties of index.js are described after //s.

const classifier = knnClassifier.create(); // Transferring the transfer learning model

// A tandem classification model is created on which we will train with our data. const webcamElement = document.getElementById('webcam'); // A webcam element is created.

// Audio files are defined by specifying their addresses on the computer.

var audio0 = new Audio("sesler/daralan_yol_levhasi.mp3"); var audio1 = new Audio("sesler/dur_levhasi.mp3");

var audio2 = new Audio("sesler/gevsek_malzemeli_zemin.mp3"); var audio3 = new Audio("sesler/hiz_siniri_levhasi.mp3");

var audio4 = new Audio("sounds/two_yonlu_trafik.mp3"); var audio5 = new Audio("sounds/lit_islet_cihazi.mp3"); var audio6 = new Audio("sounds/carpeted_yol.mp3");

var audio7 = new Audio("sounds/slippery_road.mp3")

var audio8 = new Audio("sounds/controlled_railway.mp3"); var audio9 = new Audio("sounds/uncontrolled_railway.mp3")

var audio10 = new Audio("sesler/okul_gecidi.mp3"); var audio11 = new Audio("sesler/park_yapilmaz.mp3");

var audio12 = new Audio("sesler/saga_tehlikeli_viraj.mp3"); var audio13 = new Audio("sesler/tasit_giremez.mp3")

var audio14 = new Audio("sounds/dangerous_egim.mp3"); var audio15 = new Audio("sounds/u_donusu_yasak.mp3"); var audio16 = new Audio("sounds/vahsi_haylar.mp3");

var audio17 = new Audio("sounds/yaya_gecidi_levhasi.mp3"); var audio18 = new Audio("sounds/yol_calismasi.mp3")

var audio19 = new Audio("sounds/yol_ver_levhasi.mp3"); var audio20 = new Audio("sounds/CantinaBand3.wav")

let net;

async function app() { console.log('Loading mobile net...')

// This loads the mobilenet model used in transfer learning.

net = await mobilenet.load(); console.log('Model loaded successfully')

// This is where we take pictures from the webcam.

const webcam = await tf.data.webcam(webcamElement);

// read the image from the webcam and assign the appropriate class number.

const addExample = async classId => {

// Capture an image from the webcam. const img = await webcam.capture();

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var audio4 = new Audio("sounds/two_yonlu_trafik.mp3"); var audio5 = new Audio("sounds/lit_islet_cihazi.mp3"); var audio6 = new Audio("sounds/carpeted_yol.mp3");

var audio7 = new Audio("sounds/slippery_road.mp3")

var audio8 = new Audio("sounds/controlled_railway.mp3"); var audio9 = new Audio("sounds/uncontrolled_railway.mp3")

```
var audio10 = new Audio("sesler/okul_gecidi.mp3"); var audio11 = new Audio("sesler/park_yapilmaz.mp3");

var audio12 = new Audio("sesler/saga_tehlikeli_viraj.mp3"); var audio13 = new Audio("sesler/tasit_giremez.mp3")

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var audio16 = new Audio("sounds/vahsi_haylar.mp3");

var audio17 = new Audio("sounds/yaya_gecidi_levhasi.mp3"); var audio18 = new Audio("sounds/yol_calismasi.mp3")

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// This is where we take pictures from the webcam.

const webcam = await tf.data.webcam(webcamElement);

// read the image from the webcam and assign the appropriate class number.

const addExample = async classId => {

// Capture an image from the webcam. const img = await webcam.capture();

// The captured image is first analysed by the transfer learning model and then by our

// tandem classification model. The image is then blurred and the system is

// ready to take a new image

const activation = net.infer(img, 'conv_preds'); classifier.addExample(activation, classId)

img.dispose();

// Adds an instance to the associated class when the buttons are pressed.

// butonlara basıldığında ilgili sınıfa bir örnek ekler. document.getElementById('class-a').addEventListener('click', () => addExample(0)); document.getElementById('class-b').addEventListener('click', () => addExample(1)); document.getElementById('class-c').addEventListener('click', () => addExample(2)); document.getElementById('class-d').addEventListener('click', () => addExample(3)); document.getElementById('class-e').addEventListener('click', () => addExample(4)); document.getElementById('class-f').addEventListener('click', () => addExample(5)); document.getElementById('class-g').addEventListener('click', () => addExample(6)); document.getElementById('class-h').addEventListener('click', () => addExample(7)); document.getElementById('class-i').addEventListener('click', () => addExample(8)); document.getElementById('class-j').addEventListener('click', () => addExample(9)); document.getElementById('class-k').addEventListener('click', () => addExample(10)); document.getElementById('class-l').addEventListener('click', () => addExample(11));

document.getElementById('class-m').addEventListener('click', () => addExample(12));
document.getElementById('class-n').addEventListener('click', () => addExample(13));
document.getElementById('class-o').addEventListener('click', () => addExample(14));
document.getElementById('class-p').addEventListener('click', () => addExample(15));
document.getElementById('class-q').addEventListener('click', () => addExample(16));
document.getElementById('class-r').addEventListener('click', () => addExample(17));
document.getElementById('class-s').addEventListener('click', () => addExample(18));
```

```
document.getElementById('class-t').addEventListener('click', () => addExample(19));
document.getElementById('class-u').addEventListener('click', () => addExample(20));

while (true) {

if (classifier.getNumClasses() > 0) { const img = await webcam.capture();

// Get the activation from mobilenet from the webcam. const activation = net.infer(img, 'conv_preds');

// Probabilistically calculates which class the image belongs to from the classification model. It takes a value between 0 and 1.

// 0: %0, 1: %100

// The name of the character corresponding to the class with the highest probability is displayed and the audio file is played.

const classes = ['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U'];

document.getElementById('console').innerHTML = `

<h1>prediction: ${classes[result.label]}</h1>\n

<h1>probability: ${result.confidences[result.label]}</h1>

if (result.label == 0){

document.getElementById("console").innerHTML="<h1>Daralan Yol Levhası</h1>"; audio0.play();}

else if (result.label == 1) { document.getElementById("console").innerHTML="<h1>Dur Levhası</h1>"; audio1.play();}

else if (result.label == 2) { document.getElementById("console").innerHTML="<h1>Gevşek MalzemeliZemin</h1>";audio2.play();}

else if (result.label == 3) { document.getElementById("console").innerHTML="<h1>Hız Sınırı Levhası</h1>"; audio3.play();}

else if (result.label == 4) { document.getElementById("console").innerHTML="<h1>İki Yönlü Trafik</h1>"; audio4.play();}

else if (result.label == 5) { document.getElementById("console").innerHTML="<h1>Işıklı İşaret Cihazı</h1>"; audio5.play();}

else if (result.label == 6) { document.getElementById("console").innerHTML="<h1>Kasisli Yol</h1>"; audio6.play();}

else if (result.label == 7) { document.getElementById("console").innerHTML="<h1>Kaygan Yol</h1>"; audio7.play()}

else if (result.label == 8) { document.getElementById("console").innerHTML="<h1>Kontrollü DemiryoluLevhası</h1>"; audio8.play();}

else if (result.label == 9) { document.getElementById("console").innerHTML="<h1>Kontrollü Kavşak</h1>"; audio9.play();}

else if (result.label == 10) { document.getElementById("console").innerHTML="<h1>Okul Geçidi</h1>"; audio10.play();}

else if (result.label == 11) { document.getElementById("console").innerHTML="<h1>Park Yapılmaz</h1>"; audio11.play();}
```

```
else if (result.label == 12) { document.getElementById("console").innerHTML="<h1>Sağa Tehlikeli Viraj</h1>"; audio12.play();

else if (result.label == 13) { document.getElementById("console").innerHTML="<h1>Taşıt Giremez</h1>"; audio13.play();}

else if (result.label == 14) { document.getElementById("console").innerHTML="<h1>Tehlikeli Eğim</h1>"; audio14.play();}

else if (result.label == 15) { document.getElementById("console").innerHTML="<h1>U Dönüşü Yasak</h1>"; audio15.play();}

else if (result.label == 16) { document.getElementById("console").innerHTML="<h1>Vahşi Hayvanlar</h1>"; audio16.play();}

else if (result.label == 17) { document.getElementById("console").innerHTML="<h1>Yaya Geçidi</h1>"; audio17.play();}

else if (result.label == 18) { document.getElementById("console").innerHTML="<h1>Yol Çalışması</h1>"; audio18.play();}

else if (result.label == 19) { document.getElementById("console").innerHTML="<h1>Yol Ver</h1>"; audio19.play();}

otherwise {document.getElementById("console").innerHTML="<h1>Levha Yok</h1>";}

// Belleği serbest bırakmak için tensörü atın. img.dispose();}

Wait for tf.nextFrame();}}
```

3. Results and Discussions

As can be seen in Table 1 and Table 2, after the introductions with 10 and 20 photos per traffic sign, 2 different road trials were carried out and the accuracy tables were obtained as follows.

With the developed system, driver errors caused by inattention and/or ignorance will be minimised. As a result, we believe that traffic will be safer and road accidents will be reduced. This system can help drivers while driving and can also be used in traffic sign training. As the number of photographs used in the training of the system increases, so does the accuracy of the system.

The success of the system is directly proportional to the samples selected during training. Taking samples at different angles and distances, at different lighting levels, will allow the system to generalise.

The success of the system will increase as the number of samples taken per class increases.

The exposure speed, sensor size and resolution of the camera used are important as they affect the quality of the image.

Table 1 Accuracy table obtained from the system introduced with 10 photos per sign in a vehicle travelling at a constant speed of 20 km/h.

	Signs predicted by the system							
Signs on the street		**Pedestrian Crossing**	**Sign Illuminated Sign**	**Sign of Crime**	**Maximum Speed Signboard**	**Stop Sign**	**No Sign**	**Success rate**
	Pedestrian Crossing	4		1				80%
	Sign Illuminated Sign		3		1	1		60%
	Sign of Crime			3			2	60%
	Maximum Speed Signboard	2			3			60%
	Stop Sign		2			3		60%
	No Sign	1				2	2	40%
		Average performance						**60%**

Table 2 Accuracy table obtained from the system introduced with 20 photos per sign in a vehicle travelling at a constant speed of 20 km/h.

	Signs predicted by the system							
Signs on the street		**Pedestrian Crossing**	**Sign Illuminated Sign**	**Sign of Crime**	**Maximum Speed Signboard**	**Stop Sign**	**No Sign**	**Success rate**
	Pedestrian Crossing	5						100%
	Sign Illuminated Sign		4				1	80%
	Sign of Crime		1	4				80%
	Maximum Speed Signboard	1			4			80%
	Stop Sign		1		1	3		60%
	No Sign			1		1	3	60%
		Average performance						**90%**

The developed system does not record during training and does not create a database. For this reason, training must be repeated if the Internet connection is lost or the computer is restarted. It also only works on the local computer. In later versions to be developed, the system can be hosted on the Internet using cloud applications provided by companies such as Amazon and Google. Thanks to these cloud services, the photos used for training and the training results can be stored and the system does not need to be retrained each time. In addition, multiple users can connect at the same time and train the system as they wish.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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